



**White Sands Missile Range 2007 Urban Study:
Flow and Stability Around a Single Building
Volume 1 – Field Study Overview**

**by Gail Vaucher, Manuel Bustillos, Robert Brice, Sean D’Arcy,
Ron Cionco, Felicia Chamberlain, Joseph Trammel, Saba Luces,
Richard Padilla, and Jimmy Yarbrough**

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Army Research Laboratory

White Sands Missile Range, NM 88002-5501

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Summary

The *WSMR 2007 Urban Study: Flow and Stability around a Single Building, Volume 1 – Field Study Overview* is the first of a series of reports describing the *WSMR 2007 Urban Study* research project. In the Field Study Overview, we describe the foundational scientific and engineering aspects of the airflow and stability field study and provide an administrative report on the field study execution with its associated research application drills. The six mission objectives driving this project were derived from three general areas: urban atmospheric research, technology advancements, and research applications. These three areas are the foundational pillars for the report's background (chapters 1 and 2), test plan (chapter 2), field study execution (chapter 3 and 4), and preliminary results (chapter 5). Concluding this technical report are comments by Test Director Gail Vaucher, which describe the many beneficiaries of this field study/research work.

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1. Introduction

On 2007 February 22, terrorists released a noxious chlorine gas in the southwestern Bayaa neighborhood of Baghdad. Six people were killed and more than 70 persons hospitalized with respiratory problems (1). If military troops had been in the Bayaa neighborhood during this event, would they have been armed with the most informative atmospheric intelligence for their response? If this scenario were to happen in a United States neighborhood, would the civil service workforce respond appropriately? Part of the *White Sands Missile Range (WSMR) 2007 Urban Study (W07US)* was designed to address both of these questions. The following report describes the *W07US*, beginning with a look at the military interest in this project and an historical review of this urban atmospheric research.

1.1 Military Interest in Atmospheric Field Measurements

Atmospheric urban field measurements are the foundation for extracting repeatable, and therefore forecastable, urban atmospheric patterns. These patterns are parameterized into mathematical algorithms. The algorithms are integrated into Army models, which then contribute to Army decision aids and become tools for improving military efficiency and effectiveness in the urban environment.

1.2 Historical Review of the WSMR Urban Study Research

Prior to 2001, an empirical model of the diurnal variations in optical turbulence identified a daily transition between stable and unstable stability that greatly enhanced the maximum ranges for target acquisition for short periods of the day. This *Neutral Event Forecast Model* utilized at a government test facility required wider verification. Therefore, in 2001, the U.S. Army Research Laboratory (ARL) conducted a series of field studies:

1. To verify the *Neutral Event Forecast Model* in a desert site unique from the one in which the model was developed, and
2. To characterize surface layer stability transition patterns in a rural environment.

The test site was at “Thompson Tower” site in WSMR, NM. The three field studies occurred in 2001, March (equinox), June (solstice), and September (equinox). The equipment consisted of 3 towers (32 m, 10 m, and 4 m) with thermodynamic and dynamic sensors, a global positioning system (GPS) rawinsonde, and a 924 MHz Wind Profiling Radar. While this experiment verified the *Neutral Event Forecast Model* in the open desert, a nagging question still remained: Does the *Neutral Event (Stability Transition) Forecast Model* apply to a desert urban environment?

1.2.1 WSMR 2003 Urban Study (W03US) (Pre-Test #1)

In 2003 March, the above question was addressed in the *W03US* (also known as the *JOINT URBAN2003-Pre-Test#1*). The four core objectives that drove this study were:

1. To test the design and functionality of the ARL meteorological instrumentation and data acquisition systems prior to their deployment to *JOINT URBAN2003* (JU2003¹).
2. To characterize surface layer stability transition patterns in an urban environment.
3. To qualitatively characterize airflow behavior around and above a single building as a precursor to the JU2003 field study.
4. To qualitatively verify the 1994 National Oceanic & Atmospheric Administration (NOAA)/ Environmental Protection Agency (EPA) Wind Tunnel Model results of airflow over a single building.

The test site location was a two-story, rectangular, concrete-block office building at WSMR, NM (see section 2.3). Data were acquired for two weeks in March. The equipment included four 10 m towers, one 5 m tower, and Campbell Systems measuring pressure, temperature, relative humidity, wind speed, wind direction, and solar radiation. The design of the test site layout was primarily drawn from the NOAA/EPA wind tunnel model flow field results (see figure 1) published in 1994 by Snyder and Lawson (2). A sample of these wind tunnel results is given in figure 1. Four airflow features were identified within the flow features and targeted for verification. These features included 1) Fetch Flow, 2) Accelerated Flow, 3) Velocity Deficit, and 4) Flow Reversal. The goal was to qualitatively verify the mean airflow parameters and general urban stability patterns. Figure 2 shows the *W03US* building and tower locations.

¹JU2003 was a multi-agency urban field study conducted at Oklahoma City, OK, in the summer of 2003.

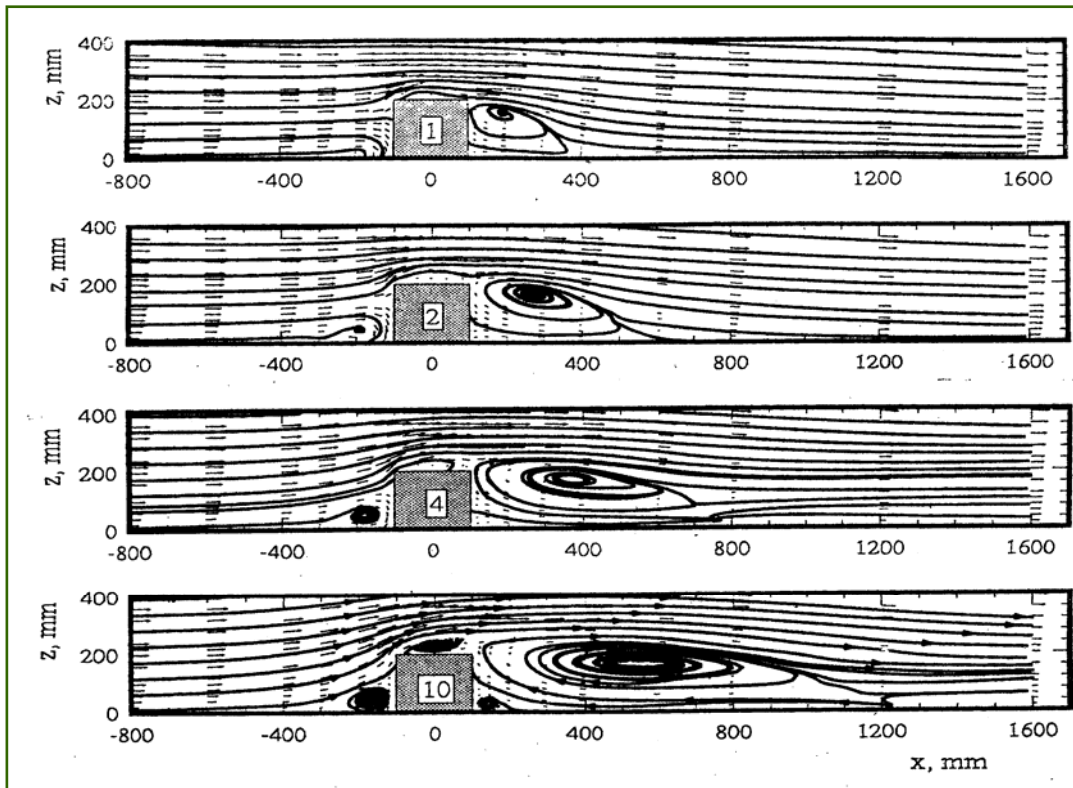


Figure 1. NOAA/EPA wind tunnel model flow field results.

NOTE: Number on building is width/height ratio; length = height (2).

BUILDING and TOWERS



Figure 2. W03US test site layout.

NOTE: Arrows indicate location of towers. Ground-based towers are labeled using compass orientations with respect to the building.

What we gleaned from the *W03US* (Phase I) were the following:

1. We verified all four attributes selected from the NOAA/EPA Wind Tunnel Study.
2. We established general stability patterns from the mean data set.
3. We documented the study with various publications and presentations (see appendix D).
4. We justified to ARL management our readiness to participate in the JU2003 project.

We also were honored by the unsolicited international recognition by urban climate expert, Dr. Timothy Oke of University of British Columbia, Canada, who requested and included *W03US* results in his 2003 North Atlantic Treaty Organisation (NATO) presentation (Banff, Canada) (3).

1.2.2 WSMR 2005 Urban Study (*W05US*)

In 2005 March, the *W05US* goals were expanded to include additional details of the urban airflow around a single building and to focus on conditions when a stable atmosphere is found around an office building. The two specific mission objectives tagged with this field study included the following:

1. To better quantify and characterize behavior of turbulent flow around and above a single building.
2. To specifically characterize surface layer stability patterns in an urban environment.

The basic site design and data acquisition were the same as the *W03US*. There were, however, several improvements. First, since the objectives required a more detailed quantification of the airflow, the Campbell Wind Monitors were supplemented and, in some cases, replaced with RM Young Ultrasonics anemometers. The Ultrasonics' quick response wind sensors allowed for 20 Hz sampling rates. Second, three of the sonics were mounted on tripods and strategically placed to capture a sample of the building leeside, side-eddy flows, and the reattachment zone airflow. Figure 3 displays the added flow features targeted for this study. Figure 4 displays the test site design. Finally, although the stability pattern focused on stable atmospheric conditions around the building, no thermodynamic/stability sensors were changed for this second phase (Phase II) of the WSMR Urban Study research.

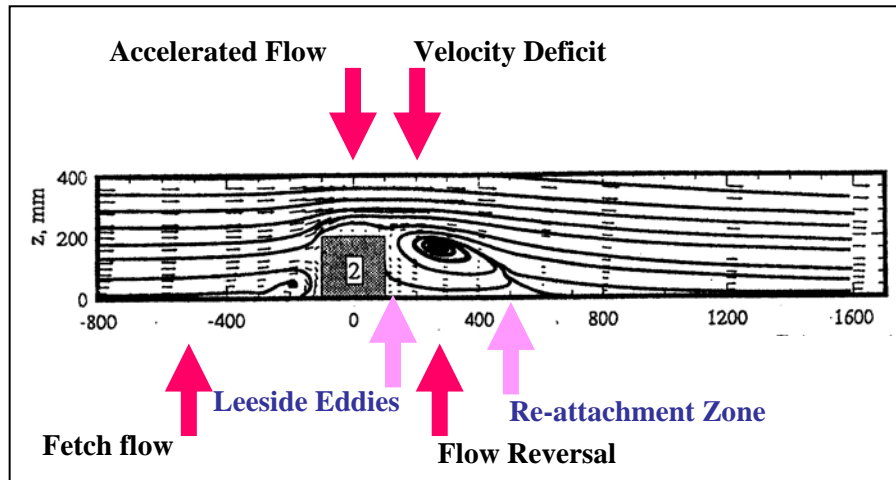


Figure 3. *W05US* flow features targeted for verification.

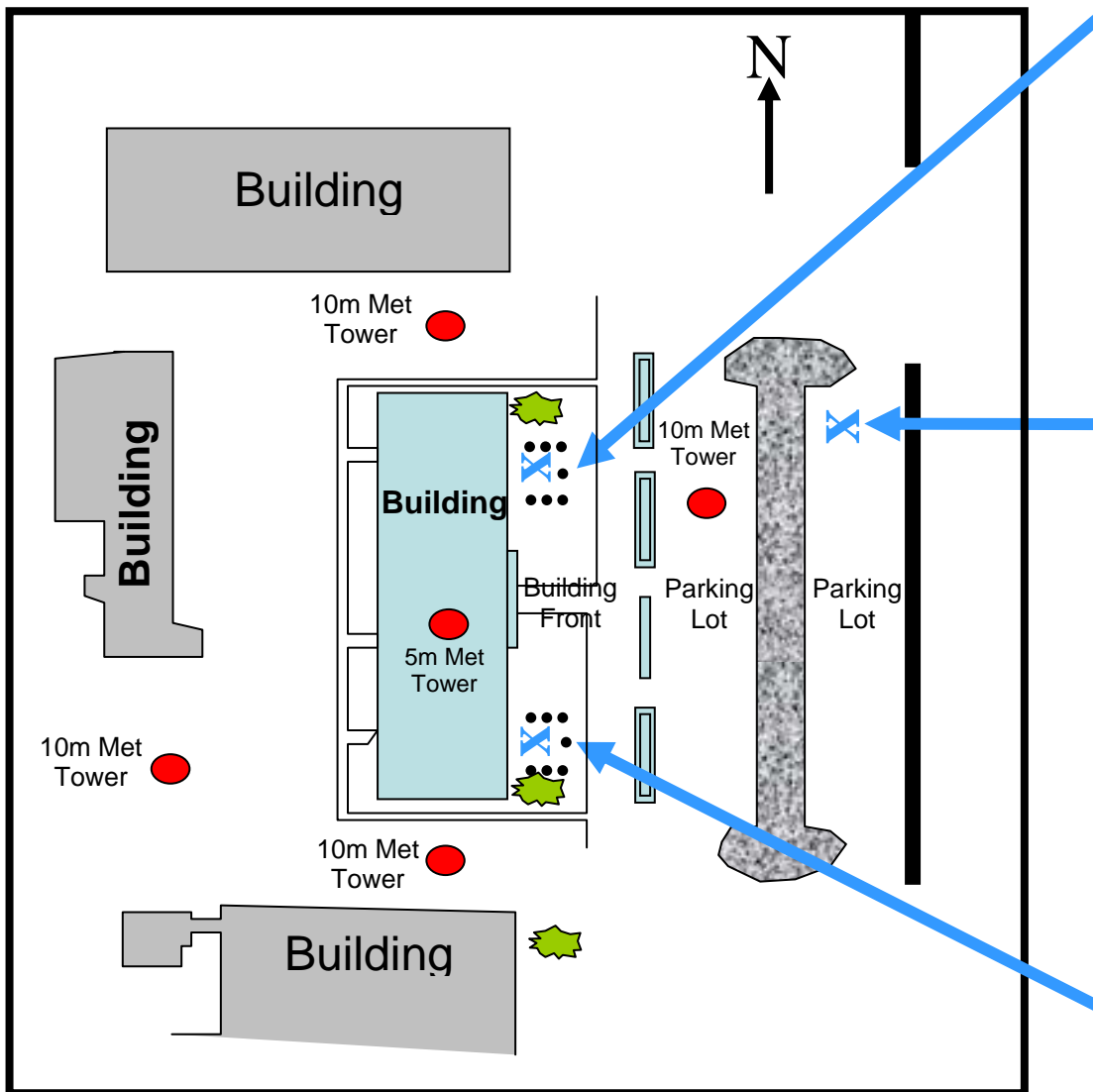


Figure 4. *W05US* test site (not drawn to scale).

NOTE: Arrows point to the three tripods added to the original *W03US* design, which only included the 5 meteorological (Met) towers (red dots).

The success of the *W05US* (Phase II) provided several advances to the urban research:

1. We improved the verification of all six airflow features defined from the NOAA/EPA Wind Tunnel Study.
2. Stable conditions were quantified around the single building, which lead to the observation that the building served as a “mini-heat island.”
3. Several ARL projects stemmed from the field study’s results, such as a collaborative effort with NOAA/EPA on the computational fluid dynamic model investigations.
4. We gained enough confidence to invite military and civilian applications to subsequent ARL urban studies at WSMR, NM.

An example of the *W05US* results is given in figure 5. This time series shows the cavity flow reported from the tower positioned northeast of the subject building. Notice that when the wind direction was from the south (0300-0800 Local Time (LT)), all three sonics report wind directions from the same general region. When the 10 m level winds (blue) report winds from the westerly direction (2000-2400 LT), the 2.5 m level (red) shows winds from the eastern quadrants. As expected, the 5 m level (green) wind directions during this flow reversal condition are from no particular direction.

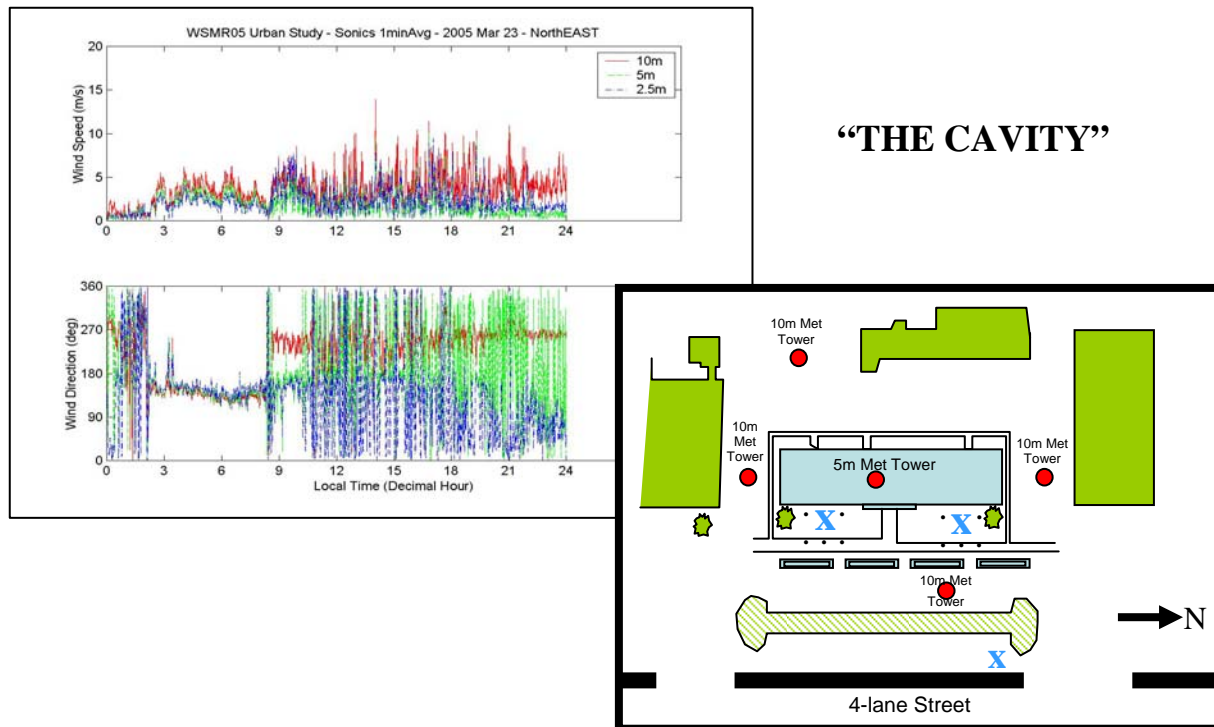


Figure 5. 2005 March: Phase II preliminary results (unprocessed data).

2. WSMR 2007 Urban Study – Overview

In March 2007, ARL conducted the *WSMR 2007 Urban Study: Flow and Stability around a Single Building (W07US)* field study. The *W07US* was focused on providing information relevant to two audiences: the urban warfighter and the urban meteorology research community.

2.1 Mission Objectives

The six mission objectives of the *W07US* were derived from three general areas: urban atmospheric research, technology advancements, and research applications. The individual objectives and their associated technical lead Point of Contacts (POC) were as follows:

1. To acquire data for verification of urban micro-meteorology models, such as ARL's Three-dimensional Wind Flow (3DWF) model and Los Alamos National Laboratory's (LANL) Quick Urban and Industrial Complex (QUIC) model. (POC: Vaucher/Cionco)
2. To characterize behavior of turbulent airflow around and above a single building. (POC: Cionco (Vaucher))
3. To characterize surface layer stability patterns in an urban environment. (POC: Vaucher)
4. To design, develop, test, and evaluate an integrated Data Acquisition System (DAS) hardware/software. (POC: D'Arcy)
5. To evaluate sensor systems for a new mobile, modular, reusable Safari unit design. (POC: Bustillos)
6. To demonstrate disaster response applications for scenarios focused on a single office building. (POC: Chamberlain/Trammel)

The first three objectives advanced the goals of the previous WSMR urban studies. That is, the data for model verification shifted the focus of the WSMR urban research from a physical model (wind tunnel) to a (urban) computer model. The two characterization objectives drove the need to quantitatively detail the flow and stability conditions. Thus, we had to increase the population and types of data acquisition resources. Objectives 4 and 5 supported the increased resource requirements by accepting the challenge to develop and evaluate the tools needed for a successful field study execution. The applications objective, Objective 6, originally had both a military and civilian component. The military component consisted of micro-unmanned aircraft systems (UASs) being flown around the urban environment. Unfortunately, the UAS requirement for 100 buildings around which their flight path would be mapped was not something we were able to accommodate at this time. Therefore, that piece of the study was postponed until a later time. The civilian application requirements, however, were within reach of the *W07US*'s resources and will be described in section 2.2.

2.2 Civilian Applications

Since the 2001 September 11 terrorist destruction of the two World Trade Center towers in New York City, natural and manmade threats to the workforce have become an increased concern. While Soldiers protect the nation, individual Civil Service employees need to be prepared to respond intelligently to threats as well. Force Protection exercises or drills provide a controlled environment in which employees can translate viewgraph training into practical understanding. By coupling force protection drills with coincident atmospheric measurements, the question of whether the standard disaster response procedures are appropriate and optimal with respect to contemporary understanding and decision aid tools can be addressed. One of the significant enhancements made with the *W07US* was the addition of a Disaster Response/Force Protection Applications Objective. This objective included the integration of three simulated, manmade, atmospheric threat/hazard scenarios relevant to the ARL workforce. The scenarios and their airborne hazard were as follows:

- Fire (Civilian Hazard: smoke and extreme convection),
- Simulated Bomb Threat (Civilian Hazard: hazardous/non-hazardous plume debris), and
- Shelter-in-Place (SIP) (Civilian Hazard: chemical spill by chemical transport vehicle).

Workforce drills were designed and executed around each of these airborne threat scenarios. The Post-*W07US* goal for this objective is to 1) evaluate the executed civilian response procedures against coincident atmospheric data and 2) offer recommendations based on an informed understanding.

NOTE: An excellent example of drill relevancy to the WSMR workforce occurred exactly one month after the SIP drill (almost to the minute), when ARL-WSMR employees witnessed two naturally formed threats to their worksite, requiring them to implement the SIP threat response for real (see appendix C).

2.3 Field Study Subject Building

The subject building selected for the *W07US* was the same two-story, rectangular office building used in the *W03US* and *W05US* urban field studies at WSMR, NM (section 1). This building was concrete cinder-block with a nearly flat roof. To the south of this building was a similarly-shaped single story building. To the west was a stair-stepped two to one story building. To the north was a matching two-story building. Nearly level gravel and dirt surfaces were between these buildings. East of the building were a grassy area, a sidewalk, and a paved 4-row parking lot. During the acquisition period, no automobiles were permitted to utilize the parking lot.

The test site design was based on urban computer models, airflow/stability characterization requirements, and available equipment and personnel resources. The resulting design kept the original four towers surrounding the building in the same locations (see figure 6). The roof tower was moved slightly from the previous studies due to non-*W07US* objects co-resident on the roof. The “new” towers included a leeside southeast cavity flow tower, three reattachment zone tripods (versus the single reattachment zone tripod used in *W05US*), two partial towers for the side-eddy locations, and a canyon flow tripod. The side eddy partial towers supported the goal of quantifying these leeside eddy features in a 2- and 3-dimensional manner (versus the *W05US* approach, which used a single sampling point and visual tell-tail flags). In total, 12 towers/tripods were used to support 51 sensors acquiring data around the subject building. Figure 6 shows the *W07US* test site layout for the 3–12 m towers (SW, S, NE), 2–10 m towers (N, SE-cavity flow), 2-partial towers (eddy-north/south), and the 5 tripods (reattachments-N/E/S, Roof, NW canyon).



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NOTE: Just prior to the field study execution, the two 2-story-tall trees on the northeast and southeast corners of the building were unexpectedly removed. This action impacted the pre-determined locations for the side-eddy towers, and to a lesser degree, the cavity flow and reattachment towers/tripods. Figure 6 reflects the final test site layout with these trees removed.

The sensor systems mounted on each of these 12 towers/tripods consisted of an RM Young Ultrasonic Anemometer and/or a Campbell System. Each of these units will be described in section 2.5. Table 1 summarizes the tower configuration.

Table 1. Tower configuration.

Tower	# of Units	Sensors: Sonics (/unit)	System: Campbell (/unit)
12 m Tower	3	3 per unit	1 per unit
10 m Tower	2	2 per unit	1. North: 1 2. Southeast: 0
Partial Tower	2	1. Northeast: 2 2. Southeast: 3	0
6 m Tripod	3	1. Roof: 1 2, 3. NWC, RE ^a : 2	1. Roof: 1 2, 3. NWC, RE ^a : 0
2 m Tripod	2	1 per unit	0
Totals	12	25 sensors	5 systems

^aNWC = northwest canyon; RE = reattachment-east.

2.5 Meteorological Sensors

The meteorological sensors sampling the dynamic data included the Campbell Wind Monitor (model 05103) and the RM Young Ultrasonic Anemometer (model 81000). The Wind Monitor sampled every 5 s then processed this into 1-min average output. The Ultrasonic (a.k.a., Sonic) sampled data at 20 Hz and were designed to run independent from the Campbell systems. The sonic was selected for the high data rate capability, which was needed to support the post-test data analysis of turbulence. The airflow measurement sensors utilized are summarized in table 2.

Table 2. Turbulent airflow measurements employed.

Variable	Sensor	Manufacturer	Model
Wind Speed/Direction, Temperature, Speed of Sound	Ultrasonic Anemometer	RM Young	81000
Wind Direction: Located NE and SE corners of building	Fence post with flag on top		

NOTE: NE = northeast and SE = southeast.

The thermodynamic data were sampled from the Campbell System. What we refer to as “Campbell System” consisted of a Campbell CR23X micro-logger sampling data from a barometer, thermometer, humicap, wind monitor, pyranometer, and in three cases, a net radiometer. Though the micro-logger’s 1-min average output was somewhat limiting, the data acquired did capture the trends of the diurnal cycles, and these systems were available for use at the time of the field study execution. Details of the individual Campbell System sensors are listed in table 3.

Table 3. Mean flow measurements acquired by Campbell CR23X micro-logger systems.

Variable	Sensor	Manufacturer	Model	Units
Pressure	Barometer	Vaisala	PTB-101B	Millibars
Temperature	Thermometer	Campbell	T107	Celsius
Temperature/relative humidity	Thermometer/hygrometer	Vaisala	HMP45AC	Celsius/percent
Wind speed and wind direction	Wind monitor	RM Young	05103	Meter/second, and degrees
Solar radiation	Pyranometer	Kipp/Zonen	CM3	Watts/meter ²
Net solar radiation	Net radiometer	Campbell	NR-LITE	Watts/meter ²

The parameters measured from the sensors during the *W07US* consisted of pressure (mb), temperature (C), relative humidity (%), wind speed (m/s), wind direction (°), and solar radiation (W/m²). To optimize the sampling quality, the turbulent sensors (sonics) were mounted on the windward (west) side of the towers and the mean flow sensors (Campbell system sensors) were attached to the leeward (east) tower side. The solar radiation sensors were placed on the unobstructed south side of the tower.

2.6 Data Acquisition Period

W07US data were acquired from 2007 March 19–April 2. The two-week acquisition ran 24 hours per day, 7 days a week. The data acquisition period selected was based on 1) atmospheric stability requirements (March equinox was selected to minimize the systematic seasonal effects on the daily heating/cooling cycles) and 2) atmospheric dynamics requirements (March/April NM windy season was selected to optimize field study conditions pertinent to the airflow characterization and model verification objectives).

2.7 Test Plan – Overview

Conducting a major field study requires the coordination of many details and personnel over an extended time period. Table 4 summarizes the four key phases for *W07US*.

Table 4. Four key phases for *W07US*.

Key Phase	Dates of Execution
Preparations	2006 Jul–2007 Mar
Pre-Study Calibrations	2007 Feb/Mar
Field Portion	2007 Mar/Apr ^a
Post-Study Calibration and Preliminary Summary	2007 Apr/May

^a 2005 Mar 19– Apr 2.

Section 3 will elaborate, in chronological order, the significant milestones crossed during the execution of each of these phases.

2.8 Personnel

The highly successful field portion of the *W07US* project was due to the team effort of 10 ARL professionals. Each professional was a lead, as well as a team player for the six mission objectives. Table 5 summarizes their primary responsibility(s).

Table 5. *W07US* personnel.

Participant	Principle Investigator for...	Open House Speaker	Comments
Vaucher	Research Objectives #1, #3, (#2)	Yes	<i>W07US</i> Test Director
Brice*		No	Lead Met Tech-contributed to all Objectives.
Bustillos*	Technology Objective #5	Yes	Acting Test Director
Chamberlain	Applications Objective #6	Yes	
Cionco	Research Objectives #1, #2	Yes	Emeritus starting January 2007
D'Arcy*	Technology Objective #4	Yes	
Luces		Yes	Lead for large-scale Met data and 3DWF.
Padilla		No	Lead for Flat Screen Technology
Trammel	Applications Objective #6	Yes	
Yarbrough		No	Tower Setup Consultant

NOTE: Successful field studies often inspire contributions that are “above and beyond” the call of duty. When such voluntary contributions are given, the Test Director recognizes the exceptional professional. Since 90% of the participants showed this “going the extra mile” characteristic, she had to narrow the traditional criterion for the “distinguished” colleague to those whose voluntary “above and beyond” contributions spanned the entire start-to-finish *W07US* field measurement phase. The three colleagues that fell within this revised definition are distinguished with an asterisk (*).

Some of the additional individuals and groups who provided significant contributions to this project are listed below. Their area(s) of contributions follows their name.

- Chief Davis and Associates: WSMR Fire Department-Smoke Release and Safety Drill.
- Fort Bliss Explosive Ordnance Detachment (EOD): Security Training.
- ARL Security Office: Security and Safety Drills (Drills).
- Mr. Felipe Chavez: BuyIt purchases and in-field communications.
- Ms. Gina Franco: In-field and Open House communications.
- Mr. Hilario Flores: Logistics - assisted with equipment setup and teardown.
- Mr. Daniel Bustillos: Logistics, assisted with equipment setup.
- Technical Publications: Open House and Drills flat screen presentations and reports.
- WSMR Audio-Visual: Documented the smoke release and public relations events.

2.9 Costs

One of the benefits from the feasibility phase of this field study was a 79% reduction in the required costs needed for *W07US* execution. The original estimated cost for equipment requested was slightly over \$65K. After thoroughly reassessing the available and functional inventory, what we actually spent was approximately \$13.5K. Labor costs did not utilize comp time. However, we did employ the more flexible ARL credit hour program for the four core persons. Total time donated (above the normal 40 h workweek) to the research effort was 155 h. This was generously contributed by five individuals.

3. Project Milestones

The Test Director has often been asked what is required to conduct a successful major field study. In a nutshell, the essential elements include planning, organizing and research team cooperation. One of the products generated by this *W07US* included the creation of various templates for future field studies. In this Project Milestones chapter, we answer the above administrative question by presenting a chronological outline (template) of the significant milestones from the four key phases of the *W07US*:

- 2006 Jul–2007 Mar: Preparations.
- 2007 Feb/Mar: Pre-Study Calibrations.
- 2007 Mar/Apr: Field Portion (actual dates: 2005 Mar 19– Apr 2).
- 2007 Apr/May: Post-Study Calibration and Preliminary Summary.

3.1 Fiscal Year (FY)06: 2006 (Fourth Quarter)

- Jul–Sep: *W07US* white paper submitted for FY07 (2006 July).
W07US budget page submitted for FY07 (2006 Aug).
Personnel Demonstration Objectives written in support of *W07US*.
First *W07US* Group Coordination Meeting (2006 Aug 29).

3.2 FY07: 2006 (First Quarter)

- Oct/Nov: Drafted *W07US* Test Plan and Method.
Identified hardware and software requirements.

- Nov/Dec: Evaluated feasibility of executing the *W07US* in March of 2007.
Surveyed and evaluated all required, available hard/software equipment.
Defined all required purchases and solicited approval.
Finalized *W07US* Plan—All participants and supervisor initialed Test Plan.

3.3 FY07: 2007 (Second Quarter)

- Jan: Initiated and received Safety, Security, and WSMR permissions.
Made hardware purchases—first item arrived on targeted date.
Evaluated equipment as purchases arrived; integrated new with older equipment.
W07US Open House: Agenda defined.
Audio-visual arrangements initiated; non-Battlefield Environment Division (BED) funding provided.
- Feb/Mar: Open House-initiated presentation approvals; presentation dry runs given at weekly *W07US* meetings.
Created data monitoring software for daily evaluation of all 51 sensors during field study.
Received permissions for wireless technology and frequency clearance.
Laptop order unattainable before field *W07US*; ARL-WSMR colleagues lend laptops.
Pre-Study Calibration:
 - Set up/completed calibration for Campbell and RM Young systems (51 sensors).
 - Began daily weather forecasts to optimize opportunity for good calibration data.
 - Beta tested data monitoring software using daily calibration data.
- Mar 5-16: Field Site Setup:
Installed 12-towers/tripods, 51 sensors, and the data acquisition systems.
Daily weather forecasts provided to support personnel safety during installation.

Final tower sensor alignment completed with volunteered WSMR bucket truck.

- Mar 19-Apr 2: FIELD STUDY:

Acquired data from all sensors 24 hours/day and 7 days/week.

Daily Monitoring: Downloaded/plotted/evaluated data from all 51 sensors.
- Mar 26, 27: WSMR 2007 Urban Study Open House.
 - Mar 26: ARL safety and security training for Disaster Response Drills.
 - Mar 27: W07US Open House, walking tour and new flat screen technology demonstrated.
 - Mar 27: Commanding General of Research, Development, and Engineering Command (RDECOM) Major General (MGEN) Nadeau and the government Laboratory Directors visit W07 Test Site. Nadeau voluntarily extended visit 3 times longer than allocated. Kudos were given from BED Division Chief.
- Mar 28: W07 Smoke Release. This was originally part of Fire/Evacuation Drill. NOTE: On Mar 23, independent of W07US project, BED Division Chief postponed Fire Drill, which rescheduled all subsequent drills.
- Mar 29: Fire/Evacuation Drill (originally scheduled for Mar 28). The WSMR Fire Department and six ARL volunteer victims re-enforced the Mar 26 training.
- Mar 30: Simulated Bomb Threat Drill (originally Mar 29).
- Apr 2: Simulated Toxic Release/SIP Drill (originally Mar 30).

3.4 FY07: 2007 (Third Quarter)

- Apr 3: Re-measured sensor placement on all 12 towers/tripods (bucket truck volunteered).
- Apr 3–5 Took down Test Site equipment; all 12 towers/tripods/sensors removed by Apr 5.
- Apr 6–11: Setup (Apr 6)/executed Post-W07US Campbell Calibration.
- Apr 9–19: Setup (Apr 9)/executed Post-W07US Sonic Calibration (completed earlier than scheduled)
- Apr 10: Internal Project Review (IPR) for W07US field portion.

- Apr 27: Originally scheduled date for Post-*W07US* Calibration equipment takedown; actual date was Apr 19. Daily *W07US* weather forecasts discontinued on Apr 19.
 - Apr 23: Initiated implementation of Data Processing Plan (3 weeks earlier than scheduled, as per Division Chief interest).
 - Apr 23–May 10: Period for preparing *W07US Preliminary Summary* to supervisor.
 - May 11: Submitted *W07US Preliminary Summary* to Supervisor, as per Test Plan.
-

4. Internal Project Review (IPR)

The best way to improve field studies is for all participants to review their major milestones, lessons learned, any action items still needing to be completed and to provide comments/observations and suggestions. At the close of this field study, all 10 participants submitted and presented their responses to the following four IPR questionnaire issues: Major Milestones, Lessons Learned, Post-Study Action Items (with a POC), and Comments/Suggestions. A sample of participant remarks regarding the Milestones and the Lessons Learned is provided below. Overlapping comments/suggestions were integrated into the appropriate sections:

4.1 Major Milestones

This section consists of participant responses regarding the Major Milestone question, as it pertains to the overall *W07US* and the three mission objective areas.

4.1.1 Overall Study

The following items were declared “successfully completed”:

- Design and execution of *W07US Test Plan/Method*, which included 8 new sites and required 15 new sensors (12 for airflow and 3 for stability).
- *W07US* Open House.
- Three *W07US* Disaster Response/Force Protection Application Drills.
- Walking tour for RDECOM Commanding Gen, MGEN Nadeau.
- Execution and documentation of smoke release.
- BED lobby flat screen technology for the Open House/Drills/visitors.
- Evaluation of all 51 sensors within 24 hours of each field study day!

4.1.2 Scientific Objectives

The following items were declared “successfully completed”:

- Pre-/Post- *W07US* Side-by-Side Calibrations of all sensors.
- 14 days of urban-small building complex atmospheric data collection relevant to scientific objectives.

4.1.3 Technology Objectives

The following items were declared “successfully completed”:

- Documentation and improvement of Campbell micro-logger software programs.
- Integration of a Net Radiometer sensor into the Campbell Systems design.
- Integration of 12 additional sonics into the DAS design.
- User-friendly improvements to the sonic hardware design.
- Sonic wireless technology upgrades with automated data transfer.
- Sensor monitoring software improvements, which reduced data preparation time by 80%.

4.1.4 Applications Objectives

The following items were declared “successfully completed”:

- Execution and documentation of smoke releases from various points on and around the building.
- Fire/Evacuation Drill execution.
- Simulated Bomb Threat Drill execution.
- SIP Drill execution.
- Weather forecasts, briefings, and updates to *W07US* team members for safety.

4.2 Sample of Lessons Learned

This section consists of participant responses to the Lessons Learned question as it pertains to the overall *W07US* and the three mission objective areas.

4.2.1 Overall

- “Planning, understanding, and a great crew are the keys to a successful project.”
- Team work and dedicated persons make long term projects (such as this multiple fiscal year project) a success.

- Non-resident upper management support might come easier if only one person filled the position throughout the project's duration.
- Being invited to participate in MGEN Nadeau's WMSR visit was a project honor; the subsequent successful tour was even better.

4.2.2 Scientific Objectives

- Unplanned Test Site tree removal has a significant impact on an urban test site design.
- Though NM climatology forecasts strong, steady winds for March, this data set will have a mix of atmospheric dynamic conditions.
- Low wind conditions will be helpful with the stability objective post-study analysis.
- The much-reduced spatial and temporal scales for atmospheric patterns were very evident during the smoke release.

4.2.3 Technology Objectives

- Putting all power resources on Uninterrupted Power Supplies helped reduce opportunities for missing data.
- The 12 m towers showed improved structural stability and provided better sensor alignment.
- The new 6 m tripods were lighter weight and more structurally stable; they also had a bigger foot print.
- Not all mounting hardware is universal.
- The weather-proof connectors for sonics were much faster to deploy than the individual wiring technique.
- Universal Serial Bus (USB)-to-serial adapters can be sensitive to the addition and removal of other USB devices.
- Campbell data-logger RS232 output has unusual unprintable characters.
- Networking devices of same make/model can be less than fully compatible.
- There is much more to the flat screen technology than just plugging a computer into the big screen television.
- When combining (flat screen) presentations into one, the first briefing's master slide takes control; therefore, always check the font of the final briefing after it's merged.

4.2.4 Applications Objectives

- “Partnering with the *W07US* Project allowed...a different perspective for my Safety Stand-Down Day.” (This statement compared “hands-on” versus “viewgraph” training.)
 - “The hazard analysis provided employees an insight into the risk involved with (meteorological) towers.”
 - “The wind study is critical in the prediction of employee safety when working in hazardous conditions.”
 - “The fire drill illustrated the need to continue educating the workforce on safe evacuation procedures.”
 - “Training is more effective if followed...by hands-on exercises that depict...real work scenarios.”
-

5. Preliminary Results

The six *W07US* mission objectives were derived from three general areas: urban atmospheric research, technology advancements, and research applications. In this section, each area is evaluated with respect to the field study execution only. As the data is further processed and analyzed, additional reports and articles citing the findings will be published.

5.1 Urban Atmospheric Research

The urban atmospheric research area includes 1) the acquisition of data for model verification objective, 2) the airflow characterization objective, and 3) the stability characterization objective.

5.1.1 Model Verification Objective

The Urban Atmospheric Research objective, to acquire data for verification of urban models, was successfully completed. The field layout design and the sensor selections were based on urban models, such as ARL’s 3DWF and LANL’s QUIC model. Since neither model accounted for the site’s morphology, experience gained from the preceding field studies at this test site was integrated into the final design. When the two, two-story trees were removed from the subject building, model runs were re-evaluated with respect to the placement of the side-eddy towers. As per this first objective, data were acquired from all sensors within the model-based design. Thus, objective 1 was declared a success.

5.1.2 Airflow Characterization Objective

The second objective, to characterize behavior of turbulent airflow around and above a single building, was successfully accomplished. The field study portion of this objective was to acquire data that can be used to characterize the turbulent airflow behavior. This objective was

accomplished by designing the field study around seven airflow features, which included Fetch Flow, Velocity Acceleration over the roof, Velocity Deficit, Cavity Flow, leeside-Side-Eddies, Reattachment Zone, and Canyon Flow. Table 6 summarizes the tower/tripod placement for each of these flow patterns.

Table 6. Tower/tripod placement for each of the targeted airflow patterns

Airflow Feature	Tower/Tripod^a – Levels	Primary Sensor
Fetch	SW-3	Sonics
Velocity Acceleration	SW-1, RR-1	Sonics
Velocity Deficit	SW-1, NE-1	Sonics
Cavity Flow	SW-3, NE-3	Sonics
Side Eddies	SE-3, NE-3	Sonics
Reattachment Zone	SW-3, RN-1, RE-2, RS-1	Sonics
Canyon Flow	SW-3, SS-3, NN-2, NW-2	Sonics

^aSee Acronyms section for explanation of tower/tripod references.

The field study design also selected the time period in which the test site was, climatologically speaking, subject to the most consistent, high velocity westerly and southwesterly winds. Data were successfully acquired from all the flow feature data acquisition locations (see table 6). A preliminary qualitative assessment of the data confirmed the presence of each of these features within the data acquisition time period. As an added bonus, this dataset appears to be unique from the previous studies. That is, while previous studies reported dynamic atmospheric conditions closely aligned with climatological statistics, the *W07US* leans more toward a, climatologically speaking, statistical anomaly. This will no doubt enhance the airflow characterization opportunities around and above a single building.

5.1.3 Stability Characterization Objective

The third objective, to characterize surface layer stability patterns in an urban environment, was successfully accomplished. Stability patterns are predominantly gleaned from thermodynamic data. Therefore, the test site design included pressure, temperature, relative humidity, and solar radiation data acquired on all sides of the building. Enriching this stability research design was the addition of three Net Radiometers. These supplementary sensors were utilized on the SW, SS, and RR tower structures. These locations were selected based upon the experience gained from previous urban field studies, as well as the quest to glean a “building verses surrounding area” contrast in the net radiation. To minimize diurnal heating-cooling influences, the data acquisition dates selected were over the period of the solar equinox (equal heating/cooling within a 24 h period).

Data from all sensors were acquired during the Pre-calibration, Main Study, and Post-calibration phases of the field study. Thus, the field study phase of this Stability Objective was successfully completed. The potential for characterizing stability patterns from this dataset exceeds that of

previous field studies, in that, the 2007 environment leaned more toward a climatological-statistic anomaly. With less high wind conditions dominating the test site, the opportunities for extracting urban stable cases are greater than in previous studies. Thus, the subsequent stability data analysis phase is anticipated to be very fruitful.

5.2 Technology Advancements

The technology advancement objectives 4 (to design, develop, test, and evaluate integrated DAS hardware/software) and objective 5 (to evaluate sensor systems for Safari unit design) were both successfully executed. Technology advancements were achieved in both hardware and software. Some of the noteworthy hardware successes included new wireless technology for the 25 sonics mounted over and around a two-story building; waterproof connectors making the sonic system installation more efficient and durable; taller, more stable tripods; better-engineered 10 m mountings; and the integration of 15 new sensors. Significant software improvements included automating the wireless data download, as well as several steps of the daily sensor monitoring. Both enhancements reduced work hour requirements considerably. For example, the preparation time required for data monitoring originally took about 40 min/tower. This time was reduced to approximately 8 min/tower. Taking into account that the *W07US* more than doubled the number of towers/tripods (with respect to *W03US* and *W05US*) these improvements had very positive contributions toward the success of the project. The final challenge for the DAS objective was the arduous 24 hr/7day/week functionality, which was indeed accomplished.

The sensor evaluation efforts generated a more organized inventory of all *W07US* hardware and several recommendations for future field studies. The results from this objective were utilized by a subsequent field project, which was able to reduce the normal large number of work hours spent searching in multiple locations for functional hardware. Thus, this objective yielded a fiscal and productivity benefit for all subsequent field projects.

5.3 Applications

The Applications Objective, to demonstrate disaster response applications for scenarios focused on a single office building, was successfully completed. The disaster response applications were conducted in the form of three drills: Smoke Release/Fire Drill, Simulate Bomb Threat Drill and a Shelter-in-Place Drill. The scenario for each drill was centered on an airborne threat to the workforce of the subject building. Atmospheric measurements from all 12 towers/tripods coincided with the trained workforce response exercises. Current standard response procedures were followed and are documented in appendices A, B, and C. With the fully completed execution of this urban study application objective we now have the data to evaluate the following core questions:

1. Was the standard disaster response procedure appropriate and optimal for the actual atmospheric conditions coincident with each drill execution? If so, why? If not, why not?

2. Are the standard disaster response procedures appropriate and optimal for the test site's atmospheric/climatological conditions?
3. Should the standard disaster response guidelines be a function of onsite atmospheric airflow and stability conditions? Would the use of tools such as ARL's model-in-development, 3DWF model or perhaps, the Air Force Ocean Breeze-Dry Gulch Model be appropriate? NOTE: At the time of this writing the 3DWF model employed airflow input only, though plans for stability were being considered; the Ocean Breeze-Dry Gulch Model employs both stability and airflow in the output.
4. If disaster response guidelines include multiple response scenarios, what are the most effective methods for communicating the appropriate workforce response? For example, during the field study, standard and new communication technology were constructed and made available to all building occupants. Was this technology sufficient during the execution of the three drills? Or, would engineering a decision aid/tool lead to a more efficient response.

With the answering of each core question, the practical nature of the urban atmospheric science and technology is strengthened. The result is a very pointed research effort that can help not only the civil servant, but also better serve the Army Soldier, which is the overriding goal of the *WSMR Urban Study* Project.

6. Conclusion

ALL SIX MISSION OBJECTIVES WERE SUCCESSFULLY COMPLETED and this 10-person, 10-month (2006 Jul-2007 May) effort has provided many positive accomplishments across a broad range of areas and to a diverse group of beneficiaries. For example, the accomplishment most valued by current upper management is the opportunity to verify and build urban models. To the urban atmospheric researchers, there is the opportunity to extract repeatable atmospheric patterns characteristic around urban buildings that feed models and improve basic understanding of the urban atmospheric environment. To the engineer and technician, *W07US* has given a more efficient data acquisition system and data display capability. For future field test directors, we've provided a better organized array of functioning equipment and constructive guidance from our lessons learned. To the administrative staff, we've provided an efficient teamwork experience for successfully purchasing a large number of items over a relatively short period of time. To the supervisor, we've built a functioning team of diverse professionals eager to process the data acquired and build on what has been accomplished. To the workforce, we've given a Force Protection experience to help face life-threatening situations intelligently and successfully. To WSMR, we've given interactive emergency response experiences with a tenant workforce. To Battlefield Environment Division,

positive public relations were established with the Commanding General of RDECOM, MGEN Nadeau (2007 Mar 27), the *Missile Ranger Newspaper* (4) (2007 Apr 26), and the *Las Cruces Sun News Newspaper* (5) (2007 May 7). But most of all, the potential for improved urban atmospheric intelligence gleaned from the *W07US* field study has given ARL an opportunity to serve our U.S. Army (U.S. Military) more effectively.

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4. U.S. Army Research Laboratory. Army Research Lab Urban Study Focuses on Safety. *Missile Ranger* **2007 April 26**, 60 (16), 9.
5. Army Research Lab's Urban Study Focuses on Evacuation Safety. *Las Cruces Sun News* **2007 May 7**, 9A.
6. ARLinside, *Tornados Provide Rare And Spectacular Show For Employees At WSMR*, 2007 May 9. <https://arlinside.arl.army.mil/inside/default.cfm> (May 7, 2007).
7. Rodriguez, M.U. Tornado. *Missile Ranger* **2007 May 3**, 60 (17), 1.

Appendix A. Smoke Release and Fire Drill Summary

The first scheduled field study drill was a Fire/Smoke Release Drill, which was designed to include a smoke release during a building evacuation, volunteer victims remaining within the building, a simulated rescue by the WSMR Fire and Rescue professionals, and a participant debriefing. One of the questions we intended to address during this drill was whether the placement of personnel was indeed in a safe zone, or would they be subject to the effects of smoke inhalation. When this drill was required to split into two parts, the intended evaluation of the evacuation site with respect to the smoke-plume hazards was redefined as a post-*W07US* analysis effort, the smoke release was re-choreographed, and the original four points defining the Fire Drill success remained as designed. All four points were successfully completed. What follows documents the execution of the Smoke Release and Fire Drill events.

NOTE: The participating workforce was prepared for these drills as part of their required annual safety/security training. The actual drills satisfied the mandatory Safety Stand-down Day for ARL-WSMR.

A1. Smoke Release

On 2007 Mar 28, the *W07US* had a smoke release around Building (Bldg) 1622 at WSMR, NM. The event began with a 1300 Mountain Time (MT) Coordination Meeting—where Chief Victor Lucero of the WSMR Fire Department briefed the *W07* victim volunteers (Brice, Bustillos, D’Arcy, and Vaucher) on the banana oil smoke release devise and requirements, and Vaucher spelled out the intended smoke release choreography for the afternoon. Between 1330–1600 MT, Chief Lucero released smoke from 3 generators. Eight smoke release cases were run. The smoke was white/gray in color. Winds were strong and generally from the western quadrants. Cases 1–6 issued smoke from heights of 1–1.5 m above ground level at various points southwest and south of the building. Cases 7–8 issued smoke from a height of about 1 m above roof level on the west and east sides of the roof. Three observers with notepads were located on the building grounds and one on the roof. The observers included: smoke source (Vaucher), south of the release (Brice), north/leeside of the building (Bustillos), and roof (D’Arcy). A hired camera crew filmed and photographed the results (paid for by Chief of Staff). Various other observers joined us throughout the event. A common time stamp unified observations and data. From this exercise, we learned several correlated logistical points (power requirements, smoke release intensity, and level) and observed several unexpected and expected four-dimensional patterns. The arrangements for this event were made possible through the efforts of our Risk Management Officer and Disaster Response Principle Investigator (PI) Felicia Chamberlain.

A2. Fire/Evacuation Drill

The 2007 Mar 29 Fire/Building Evacuation, Disaster Response Drill day began with two preparation meetings. The first (0830 MT) included discussion between the Disaster Response PI Chamberlain, the lead Rescue persons (Chief Lucero and Assistant Chief Vega), and the six voluntary victims (Brice, Bustillos, D'Arcy, JGonzales, Trammel, and Vaucher). This 45-min meeting clarified the key action items and responses expected. The second meeting (1300 MT) included the key players and the video professional (Mike Smith), who briefly reviewed the actions and surveyed the area for any miscellaneous items needing attention. One such item, a vehicle parked on the west side of Bldg 1622, had to be addressed and resolved. Once completed, Chamberlain and the Fire Chief/Assistant Chief went to the first floor to initiate the fire alarm. NOTE: Earlier this day, Chamberlain issued an e-mail to the work force informing them of the impending drill.

The Bldg 1622 fire alarm went off as scheduled (approximately 1315 MT). All ARL and contractor persons in Bldg 1622 evacuated to the predetermined location. The victims and missing persons were quickly identified. Fire Inspector Bower and Chamberlain conducted searches on all three floors. Chicken Little victim was found inside his office stating that he couldn't leave until everything was turned off and secured. Orders to evacuate the building immediately were issued. Chamberlain requested 100% personnel accountability from the building Fire Warden (Creegan), who named the 3 missing employees and stated their office locations. Chief Vega relayed the information to the fire crew inside. Bower and Chamberlain entered the northwest side of the basement calling out the victim's name. The victim opened the solid lab door responding that he didn't hear the alarm. They escorted him out of the southwest rear door where he joined the two assisted victims. The two assisted victims included a wheelchair victim on the second floor and a claustrophobic victim stuck in the elevator while trying to reach the wheelchair person. The WSMR Fire/Rescue crew located both victims. Quickly and calmly, the victims were assisted out the building's southwest exit. Simulated extra oxygen was applied to each victim. The first aid persons administered levels of triage for the ailments until that portion of the drill was completed.

The ARL Safety Officer subsequently escorted the three ARL rescued-victims to the other ARL/contractor persons at the evacuation point. With all Bldg 1622 persons present, the heart attack victim suddenly fell to the pavement. Contractor Robin Hastings and Vaucher assisted the victim while Chamberlain phoned to report the incident. The first aid crew arrived and proceeded to employ the standard heart attack countermeasures. As they worked, various persons working on the patient explained the procedures to the evacuated onlookers. Once that portion of the drill concluded, spectator questions were addressed. The final victim (acid spill) surfaced as the first aid crew was collecting their heart monitoring equipment. The simulated wound was successfully addressed.

Chamberlain concluded the drill by directing the evacuated persons to the Safety Stand-down Day Debriefing in Bldg 1622. Here, WSMR Inspector Bower and Assistant Chief Vega explained priorities during a fire drill, offered suggestions for identifying the best exit, and identified the building type in which we work. They also outlined the standard (seven step) procedure for their crews when dealing with a building on fire and answered questions from the audience. The safety debriefing concluded at 1425 MT.

ARL volunteer victims were Wheelchair – Brice; Chicken Little – Bustillos; Missing person - D'Arcy; Heart Attack - Gonzales (J.); Acid spill – Trammel; and Claustrophobic trapped in elevator – Vaucher.

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Appendix B. Simulated Bomb Threat Drill Summary

The importance of understanding current, onsite atmospheric conditions during a bomb threat is tied to following safety concerns: the location of personnel outside the structure, the impacts of airborne debris/fallout, and the footprint of a subsequent toxic/lethal plume. With the successful completion of *W07US*, we are now able to correlate coincident airflow and stability measurements with the projected bomb debris/fallout and the projected toxic/lethal plume. Subsequently, we can better evaluate the effectiveness of the current standard threat response procedures. As part of the evaluation process, a summary of the Simulated Bomb Threat Drill activities is documented below.

Simulated Bomb Threat Drill

On 2007 Mar 30 around 1300 MT, a simulated Bomb Threat phone call was received by supervisor Dr. Donald Hoock. Implementing the published Bomb Threat Checklist, Hoock determined the pertinent details of the threat. Notification of the phone call was immediately conveyed to ARL security, who issued an e-mail to the entire Bldg 1622 workforce at 1306 MT. Supervisor Hoock coincidentally notified 4 specific employees to simultaneously sweep all 4 floors of Bldg 1622, informing building occupants of the threat and their need to evacuate as per requirements. The lobby flat screen was switched to a screen informing the building personnel of the in-progress, simulated bomb threat. As per instructions, three ARL employees (Hoock, Raby, and Vaucher) met ARL Security Officer (and Disaster Response PI) Trammel in the lobby. The group then walked to the targeted site (Main Conference Room) and began to conduct the simulated bomb search. The group followed the training provided by the Fort Bliss EOD. Immediately, a white bag with wires was spotted and tagged as unusual. This item was not the simulated bomb, so the survey continued. Before completing this first inspection rotation, the simulated bomb was located under the podium (a tissue box) and confirmed by the other searchers. The searchers then left the scene to the local “Bomb Threat” professional, exited the building, and joined the evacuated persons in the designated area. Outside, an additional search was conducted and an unusually placed lunch bag was identified as suspicious. Trammel confirmed the bag as the last simulated bomb of the drill. All the evacuated persons were allowed to re-enter Bldg 1622, where Trammel conducted a debriefing in the Main Conference Room. The two scenarios were reviewed and each simulated bomb was plainly shown with the contents exposed to the viewers. After a brief question/answer session and the circulation of a sign in sheet, the drill was declared completed (time was 1345 MT).

The Simulated Bomb Threat Drill participants (including those volunteered by circumstances) included:

- Mr. Joseph Trammel (Security Officer/Disaster Response PI)

- Ms. Deon Montoya (Security Officer)
- Ms. Felicia Chamberlain (Safety Officer and simulated caller)
- Dr. Donald Hooock (Inside building supervisor/inside simulated bomb searcher)
- Ms. Pam Clark (Outside building supervisor)
- Mr. Felipe Chavez (Accountability of persons)
- Mr. Manuel Bustillos (Basement informant and found the outside simulated bomb)
- Mr. Jim Cogan (1st floor informant)
- Mr. Terry Jameson (2nd floor informant)
- Mr. Ed Measure (Roof informant)
- Mr. John Raby (Inside simulated bomb searcher)
- Ms. Gail Vaucher (Inside simulated bomb searcher)

Appendix C. Shelter-In-Place (SIP) Drill Summary

The SIP drill scenario was taken from an actual event that occurred on 2007 Feb 22 in a Bagdad neighborhood—that is, a chlorine gas release. The life cycle of a toxic plume, such as chlorine gas, is a function of stability and airflow. The issue being addressed concerned personnel safety. The question asked was: Were the standard SIP drill response procedures appropriate for the coincident ambient atmospheric conditions and simulated airborne threat? A summary of the SIP drill is documented below. First, however, we document an actual nature-generated threat to the workforce that occurred exactly one month after our SIP drill. This unexpected event not only provided enrichment to the evaluation material, but also reinforced the relevancy of the urban research application objective.

C-1 Real Work Site Threat

On 2007 May 2 (Wednesday), exactly one month after the SIP drill, ARL employees directly applied their SIP Force Protection drill experience to a real worksite threat at WSMR, NM. On May 2, two tornadoes were witnessed: one was approximately 6 miles east of the WSMR main post area, and the other was 7 miles southeast of the main Post. The first tornado lasted about 10 min, while the second tornado persisted for approximately 45–50 min. A third tornado was reported north of the neighboring city of El Paso, TX (6, 7).

The Bldg 1622 workforce responded to this natural threat and subsequent WSMR Post-wide alarm by reporting to the appropriate SIP location. Though not directly related to local airflow and stability patterns, the experience gained just one month earlier (almost to the minute!) provided for a smooth execution of the 100% accountability of persons and an efficient communication with the local authorities.

C-2 SIP Drill

On 2007 Apr 2 (Monday) at 0952 MT, Disaster Response PI Trammel sent out an e-mail to the workforce, providing background information for the impending SIP drill. He wrote, "...a tractor trailer carrying chlorine gas will be escorted through the Las Cruces gate to the El Paso gate later this morning or in the early afternoon." At 1305 MT, Trammel provided the simulated SIP requirement: "...the tractor trailer, which was being escorted from the Las Cruces gate to the El Paso gate, overturned spilling 200 gallons of chlorine gas at and ... drive. Hazmat crews responded to the scene. Exposure to chlorine gas causes serious health hazards - burning of eyes and nose, nausea, choking, suffocation, excessive fluid in the lungs and death." The lobby flat screen was switched to a screen informing building personnel of the in-progress SIP drill. All Bldg 1622 occupants quickly reported to the SIP location with a 100% inventory of known building occupants taken. A verbal description of the sealing of vents, windows, and doors, as well as a sample of the sealing material was provided by Trammel. A drill debriefing

followed with the suggestion that the sealing plastic and tape be stored in the SIP rooms as a standard item. Another suggestion was that a sweep of each floor, as done during the Simulated Bomb Threat Drill, be conducted to ensure that visitors are also brought to a safe location. The drill concluded at 1320 MT. Participants included Joseph Trammel (PI), Joe Mrozinski (Security Coordinator), Felipe Chavez (Branch Accountability), Gina Franco (Branch Accountability), and the Bldg 1622 occupants.

Appendix D. WSMR Urban Study Publications

These three references are just a sample of the full list, which is available upon request.

1. Vaucher, G; Cionco, R. 2005: *Urban Warfare: Detailing Single Building Airflow, Turbulence and Stability Variation Characteristics*, Invited paper; 73rd MORS Symposium, West Point, NY, June 21–23, 2005.
2. Cionco, R. M.; Vaucher, G.; Bustillos, M.; D’Arcy, S.; Dumais, R. 2005: Field Measurements of Airflow about a Building. *Proceedings of the Tech Panel 9 Meeting on the Urban Diffusion Model*, George Mason University, Fairfax, VA, 2005.
3. Vaucher, G.; Cionco, R.; Bustillos, M. Forecasting Stability Transitions and Air Flow Around an Urban Building – Phase I, *Proceedings of the Symposium on Planning, Nowcasting, and Forecasting in the Urban Zone*, 84th AMS Meeting, January 11–15, 2004.

Acronyms

3DWF	Three-dimensional Wind Flow (Model)
ARL	U.S. Army Research Laboratory
BED	Battlefield Environment Division
Bldg	Building
DAS	Data Acquisition System
EOD	Explosive Ordnance Detachment
EPA	Environmental Protection Agency
FY	fiscal year
GPS	global positioning system
IPR	Internal Project Review
JU2003	<i>JOINT URBAN2003</i>
LANL	Los Alamos National Laboratory
LT	Local Time (Mountain Time)
MGEN	Major General
MT	Mountain Time
MVP	most valuable player
NATO	North Atlantic Treaty Organisation
NOAA	National Oceanic & Atmospheric Administration
Obj	Objective
PI	Principle Investigator
POC	Point of Contact
QUIC	Quick Urban and Industrial Complex
RDECOM	Research, Development, and Engineering Command
SIP	Shelter-in-Place

UAS	unmanned aircraft systems
USB	Universal Serial Bus
W03US	<i>White Sands Missile Range 2003 Urban Study</i>
W05US	<i>White Sands Missile Range 2005 Urban Study</i>
W07US	<i>White Sands Missile Range 2007 Urban Study</i>
WSMR	White Sands Missile Range

Acronyms for Tower/Tripod References

NOTE: All compass references are with respect to the subject building.

NE	northeast
NN	north
NW	northwest
NWC	northwest canyon
RE	reattachment zone - east
RN	reattachment zone - north
RR	roof
RS	reattachment zone - south
SE	southeast
SS	south
SW	southwest
VN	vortex-north (side eddy)
VS	vortex-south (side eddy)

Distribution List

ADMNSTR DEFNS TECHL INFO CTR DTIC OCP (ELECTRONIC COPY) 8725 JOHN J KINGMAN RD STE 0944 FT BELVOIR VA 22060-6218	1 elec
US ARMY RSRCH LAB IMNE ALC IMS MAIL & RECORDS MGMT AMSRD ARL D J M MILLER AMSRD ARL CI OK TL TECHL LIB (2 COPIES) AMSRD ARL CI OK T TECHL PUB (2 COPIES) 2800 POWDER MILL ROAD ADELPHI MD 20783-1197	6 CDs
US ARMY RESEARCH LAB AMSRD CI OK TP TECHL LIB ATTN T LANDFRIED APG MD 21005	1 CD
LOS ALAMOS NATIONAL LAB SYSTEMS ENGINEERING & INTEGRATION GROUP ATTN M BROWN DROP POINT 19S SM-30 BIKINI ATOLL RD GROUP D-3 MS F607 LOS ALAMOS NM 87545	1 HC
PACIFIC NORTHWEST NATIONAL LAB ATTN DR J DROPPA JR 902 BATTELLE BLVD PO BOX 999 RICHLAND WA 99352	1 HC
US ARMY RSRCH LAB AMSRD ARL CI ED ATTN G VAUCHER WSMR NM 88002	14 CDS, 12 HCS
TOTAL	36 (14 HCs, 1 elec, and 21 CDs)